Current Research in Environmental & Applied Mycology (Journal of Fungal Biology)
8(2): 254–281 (2018) ISSN 2229-2225

www.creamjournal.org **Article**
Doi 10.5943/cream/8/2/10

Effects of Land Use on the Diversity of Macrofungi in Kereita Forest Kikuyu Escarpment, Kenya

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Njuguini SKM, Muchane MN, Wachira P, Okoth S, Muchane M, Saado H 2018 – Effects of Land Use on the Diversity of Macrofungi in Kereita Forest Kikuyu Escarpment, Kenya. Current Research in Environmental & Applied Mycology (Journal of Fungal Biology) 8(2), 254–281, Doi 10.5943/cream/8/2/10

Abstract

Tropical forests are a haven of biodiversity hosting the richest macrofungi in the World. However, the rate of forest loss greatly exceeds the rate of species documentation and this increases the risk of losing macrofungi diversity to extinction. A field study was carried out in Kereita, Kikuyu Escarpment Forest, southern part of Aberdare range forest to determine effect of indigenous forest conversion to plantation forest on diversity of macrofungi. Macrofungi diversity was assessed in a 22 year old *Pinus patula* (Pine) plantation and a pristine indigenous forest during dry (short rains, December, 2014) and wet (long rains, May, 2015) seasons. Field and laboratory methods included recording abundance and presence of fruiting bodies, taxonomic work and analysis of diversity in terms of density, species diversity indices and richness. A total number of 224 species were distributed across 28 families and 76 genera. Macrofungi species from families of Agaricaceae (20%), Mycenaceae (13%), Polyporaceae (10%) and Tricholomataceae (9%) were commonly represented taxa in the ecosystem. Most of the macrofungi recorded were saprophytic, mostly colonizing the litter and wood (41% and 36% respectively) based substrates, followed by soil organic matter species (15%). Ecto-mycorrhizal fungi (5%) and parasitic fungi (3%) were the least represented. Indigenous forests (natural ecosystems) recorded a wide range of mushroom assemblage (average of 6.5 species in a 400m^2 plot and 3.5 individual fruiting bodies in 1m^2 plot) compared to pine plantation forest. Conversion of indigenous forest to pine plantation altered species composition, but did not affect species diversity. More than 50% of the total macrofungi species were encountered during the wet season. Our results confirm diverse macrofungi community in forested ecosystems in Kenya, and need for their conservation.

Key words – Composition – Density – *Pinus patula* – Plantation forest – Seasonality – Species richness

Submitted 4 October 2017, Accepted 30 March 2018, Published 2 April 2018
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Introduction

Tropical forests are a haven of biodiversity hosting the richest macrofungi diversity in the world supporting higher diversity compared to the temperate zones (Hawksworth 2001, Kenya 2015). However, over past three decades unsustainable human activities that include charcoal burning, illegal logging, deforestation and encroachment and deliberate conversion of forested ecosystems to other land use has decreased available habitat for wide range of species eventually affecting the ecosystems functioning (Koh & Wilcove 2008). Although effect of indigenous forest conversion to other land uses changes on other taxa (flora and fauna), some organisms seem to have received great attention and have been adequately studied (Angelini et al. 2015). However, very little information exist on macrofungi diversity, community structure and population dynamics (Hawksworth 1991, Amaranthus 1998, Hawksworth & Rossman 1997, Varese et al. 2011, Ventullera et al. 2011, Paz et al. 2015). Consequently, macrofungi diversity is often overlooked during management and conservation of forested ecosystems.

Macrofungi (Mushrooms or macromycetes) are fruit bodies visible to the naked eye (Chang & Miles 1992) and a representative of invisible extensive belowground mycelia from the Fungi Kingdom. It is estimated that there are up to 3.8 Million species updated from the previous estimates of 1.5 million. This recent update indicates only 8 % of this figure has been described and therefore enhanced taxonomic work in fungi is required (Hawksworth 2001, Mueller et al. 2005, Hawksworth 2012, Hawksworth & Luecking 2017). In their natural condition, macrofungi community play key roles in maintenance of plant community by enhancing nutrient cycling through decomposition processes (López-Quintero et al. 2012, Ambrosio et al. 2015). Macrofungi also contribute greatly to local livelihoods through provision of food and income (Thatoi & Singdevsachan 2014, da Fonseca et al. 2015). Increased interest on macrofungi have led to the development and growth of dyes, pharmaceuticals, organic acids, hormones, animal feeds and beverage processing industries (Pushpa & Purushothama 2012). Despite the vital role of macrofungi in both natural and agro-ecosystems, scanty information exists about their interactions within the forest ecosystems and the impacts forest disturbances has on their diversity and species composition (Claudia et al. 2015).

Approximately 25,000 and 7,000 of animals and plants respectively have been described and documented in Kenya compared to only 2,071 species of fungi (Kost 2002, Tibuhwa et al. 2011, Gateri et al. 2014).Yet, over 50,000 species of fungi has been reported to exist under various habitats in Kenya (Kenya 2015). However, information about their diversity and factors controlling species composition are not yet fully studied. Forest disturbances and land use changes are known to influence plant community and fungal community are sensitive to such changes (Bader et al. 1995). Macrofungi species diversity and composition are specifically favored by presence of favorable macro and microclimate (humid conditions, temperature). They also associate with reduced anthropogenic disturbances, high plant diversity and composition and accumulation and availability of degradable substrates such as plant litter, readily available degradable wood substrates and accumulation of humus or organic matter in soil (Bässler et al. 2010, Tibuhwa et al. 2011, Pushpa & Purushothama 2012). Ecosystems with diverse plant species have high turnover of litter and degradable wood consequently favoring diverse macrofungi community (Sefidi & Etemad 2015, Yamatisha et al. 2015). Indigenous forest with minimal disturbances is thus expected to host wide range of macrofungi community compared to single species forest plantations. Although both indigenous and plantation forest types may offer suitable habitats for diverse macrofungal populations, conversion of indigenous to single species forest plantation poses a threat to their macrofungi diversity (Kost 2002, Goldman et al. 2015). Such activities alter vegetation communities, tree species composition and soil factors in terms of organic matter production and quality (C: N ratios of organic matter) (Baral et al. 2015, Claudia et al. 2015). They also bring about changes in forest management practices by introducing silvicultural activities such as thinning, pruning and selective logging that have critical impacts to macrofungal community (Baral et al. 2015). Additionally, the forests have also been facing serious conservation threats as a result of unsustainable human activities, including charcoal burning, illegal logging and encroachment.

Therefore, continued environmental destruction and deforestation is a major risk to biodiversity loss of macrofungi before proper documentation and utilisation is achieved (Kost 2002, Enow et al. 2013, Malavasi et al. 2016).

In Kenya, forested ecosystems since 1970 have witnessed a deliberate conversion to plantation forest in order to introduce the fast growing exotic tree species such as *Pine* and *Eucalyptus* species and to give way to other land use changes such as agriculture (Kost 2002, Piritta 2004). The effect of these conversions on macrofungi community is not yet fully understood (Tibuhwa et al. 2011). This study was conducted in Kikuyu Escarpment forest, which is part of the world-renowned Aberdare forest. The forest is known as an important biodiversity area with flora and fauna of global significance. Specifically the study assessed macrofungi species density, species richness and diversity indices (b) categorised the different macrofungal groups into biotrophic fuctional groups (c) determined if there was variation in macrofungi composition in the indigenous and plantation forest.

Materials and methods

Study area

The study was conducted in Kikuyu Escarpment Forest (KEF), in Aberdare Range Forest. The KEF is considered an important biodiversity area, suspected to harbor high diversity of fungi due to the wide range of elevations, habitats and soil types that exist. The forest lies on the southern slopes of Aberdare Forest, 30 km north-west of Nairobi and covers an area of 37,620 ha. It is positioned at 0°56'S, 36°40'E at an altitude of 1,800.2,700 m and mean rainfall of 1500mm per year. The KEF is divided into 6 main blocks namely; Uplands, Kereita, Kieni, Kamae, Kinale, Raggia and Kijabe. This study was conducted in Kereita forest Block that covers approximately 4,720 ha of which 75% is the indigenous forest, 8% exotic tree plantation whereas shrub land, Bamboo and agricultural crops characterize the rest. Kereita forest block was selected due to availability of information on other taxas such tree and herbs species, birds and insects which can be used for interpretation of our results. The indigenous forest in Kereita forest consists of mixed bamboo forest to broadleaved forest, dominanted by *Ocotea*, *Podocarpus*, *Macaranga*, *Neoboutonia* and *Strombosia* tree species, and a remnant of *Juniperus* forest while exotic tree plantations include *Cuppressus lusitanica, Pinus patula, pinus radiate* and *Eucalyptus grandis*.

Experimental design

The macrofungi survey was carried out during the dry (short rain, December 2014) season and wet (long rains, May 2015) season in two forest types; pristine indigenous forest with minimal forest disturbance and 22 year old *Pinus patula* plantation (Pine plantation). Three forest blocks from each forest type were selected. In each forest block, 5 plots were demarcated 200m apart along 1km transects using Permanent markers (with their GPS readings). The macrofungi were sampled in 20 m x 20 m permanent sampling plot. A total of 30 plots in the two forest types were sampled .

Collection of macrofungi

In each plot, encountered macrofungi were photographed in-situ and number of fruiting bodies was recorded. All the fruiting bodies that occurred solitary and gregariously were counted and recorded. For the gregarious species, 3-10 fruit bodies were carefully removed from their substrates by holding them carefully and placed in greaseproof paper. Features of macrofungi such as phenology, flesh colour, habitat and type of substrate colonised were recorded. This was meant to help avoid the phenotypic change that is likely to occur after drying. Same species were and packaged in separate storage greaseproof papers to avoid spore contamination among the specimens. The specimens were carefully labeled before transportation to the Mycology laboratory at the National Museums of Kenya (Table 1, Fig. 1). Spore prints made from the fresh fruit bodies were used for the identification of most macrofungi that deposited spores. The fleshy specimens were then dried in the oven at 45°C. The drying period was dependent on the thickness of the fruitbodies. Finally, the specimens were preserved for later identification.

Table 1 Macrofungi specimen deposited at the National Museums of Kenya, East Africa Herbarium (NMKEAH)

Species	Locality	Code	Collectors	Voucher specimen
Mycena inclinata	KEF	KIC-47	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 400
***Mycena* sp 2**	KEF	KIG-103	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 401
Agaricus augustus	KEF	KIG-102	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 402
Agaricus inoxydabilis	KEF	KPM-181	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 403
Agaricus silvaticus	KEF	KIG-111	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 404
***Agaricus* sp 3**	KEF	KIC-34	Njuguini , Nyawira, Muchai, Saado & Kamau	NMKEA 405
Agaricus* sp *4	KEF	KPG-141	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 406
***Agaricus* sp 5**	KEF	KPM-117	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 407
***Agrocybe* sp 1**	KEF	KIC-63	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 408
***Agrocybe* sp 2**	KEF	KIC-29	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 409
Armillaria mellea	KEF	KILR-62	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 410
***Armillaria* sp 1**	KEF	KILR-93	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 411
***Armillaria* sp 2**	KEF	KIG-113	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 412
Auricalaria auricula	KEF	KIC-61	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 413
Auricalaria delicata	KEF	KGI-127	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 414
Auricalaria polytrica	KEF	KIC-60	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 415
***Bolbitius* sp 1**	KEF	KIG-109	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 416
***Bolbitius* sp 2**	KEF	KPG-164	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 417
***Bolbitius* sp 3**	KEF	KIL-82	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 418
***Bolbitius* sp 4**	KEF	KIL-95	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 419
***Chamaeota* sp**	KEF	KIG-116	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 420
***Chroogomphus* sp 1**	KEF	KPG - 159a	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 421
***Chroogomphus* sp 2**	KEF	KPM-176	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 422
***Chroogomphus* sp 3**	KEF	KPM -176	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 423
***Clavatia* sp 1**	KEF	KPG-155	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 424
***Clavatia* sp 2**	KEF	KPG-160	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 425
***Clavatia* sp 3**	KEF	KPG-166	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 426
Clavulina cristata	KEF	KILR-51	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 427
Clitocybe dilitata	KEF	KILR-73	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 428
***Clitocybe* sp 1**	KEF	KIC-46	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 429
***Clitocybe* sp 2**	KEF	KIC-53	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 430
***Clitocybe* sp 3**	KEF	KIG-137	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 431
***Clitopilus* sp 1**	KEF	KIC-06	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 432
***Clitopilus* sp 2**	KEF	KPPG-194	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 433
Conocybe* sp *1	KEF	KPPG-199	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 434
Conocybe tenera	KEF	KPG-168	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 435
Coprinus comatus	KEF	KILR-77	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 436
Coprinus disseminatus	KEF	KILR-74	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 437
Coprinus jonesii	KEF	KPG-169	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 438
***Coprinus* sp 1**	KEF	KILR-79	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 439

Table 1 Continued.

Species	Locality	Code	Collectors	Voucher specimen
***Coprinus* sp 2**	KEF	KILR-90	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 440
***Coprinus* sp 3**	KEF	KILR-96	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 441
Coprinus stercoreus	KEF	KILR-85	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 442
Crepidotus applanatus	KEF	KIG-130	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 443
***Crepidotus* sp 1**	KEF	KICO-32	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 444
***Crepidotus* sp 2**	KEF	KICO-33	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 445
***Crepidotus* sp 3**	KEF	KIG-104	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 446
Cyathus poeppigii	KEF	KIG-131	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 447
Cyathus striatus	KEF	KIL-76	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 448
Cymatoderma elegance	KEF	KIG-103	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 449
***Cyptotrama* sp**	KEF	KIG -98	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 450
***Cystolepiota* sp 1**	KEF	KIC-37	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 451
***Cystolepiota* sp 2**	KEF	KILR-70	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 452
***Cystolepiota* sp 3**	KEF	KILR-88	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 453
***Cystolepiota* sp 4**	KEF	KPPG-154	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 454
***Cystolepiota* sp 5**	KEF	KPG-185	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 455
***Cystolepiota* sp 6**	KEF	KIG-117	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 456
***Cystolepiota* sp 7**	KEF	KIG-134	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 457
***Cytolepiota* sp 8**	KEF	KIL-40	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 458
***Cytolepiota* sp 9**	KEF	KIC-91	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 459
Daldinia concentrica	KEF	KIRL-84	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 460
***Entoloma* sp 1**	KEF	KIC-26	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 461
***Entoloma* sp 2**	KEF	KIC -27	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 462
***Entoloma* sp 3**	KEF	KIC-28	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 463
Favolaschia calocera	KEF	KIC -15	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 464
Favolaschia cyathea	KEF	KPPG-78	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 465
Fayodia leucophylla	KEF	KIC-57	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 466
Fomentarius fomes	KEF	KIG-108	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 467
***Funaria* sp**	KEF	KIL-108	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 468
***Galerina* sp 1**	KEF	KIRL-89	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 469
***Galerina* sp 2**	KEF	KIG-110	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 470
Ganoderma applanatum	KEF	KIG-66	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 471
Ganoderma australe	KEF	KPM-201	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 472
***Ganoderma* sp**	KEF	KIG-104	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 473
***Gliophorus* sp 1**	KEF	KIG-108	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 474
***Gliophorus* sp 2**	KEF	KIC -7	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 475
***Gliophorus* sp 3**	KEF	KIG-110	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 476
***Gymnopus* sp 1**	KEF	KIC-30	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 477
***Gymnopus* sp 2**	KEF	KIC-49	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 478
***Gymnopus* sp 3**	KEF	KIC-58	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 479
***Gymnopus* sp 4**	KEF	KIG-120	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 480
***Gymnopus* sp 5**	KEF	KIG-119	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 481
***Gymnopus* sp 6**	KEF	KIG-139	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 482
***Gymnopus* sp 7**	KEF	KILR-59	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 483

Table 1 Continued.

Species	Locality	Code	Collectors	Voucher specimen
Gymnopus subpruinosus	KEF	KIC-21	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 484
***Handkea* sp**	KEF	KIC-39	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 485
***Hemimycena* sp**	KEF	KIC-16	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 486
***Hexagonia* sp 1**	KEF	KIC-42	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 487
***Hexagonia* sp 2**	KEF	KIC-64	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 488
Hexagonia tenuis	KEF	KILR-93	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 489
Hygrocybe conica	KEF	KPG-171	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 490
Hygrocybe persistens	KEF	KIC-5	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 491
***Hygrophorus* sp 1**	KEF	KPG-146	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 492
***Hygrophorus* sp 4**	KEF	KPGG 184	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 493
***Hygrophorus* sp 2**	KEF	KPG-163	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 494
***Hygrophorus* sp 3**	KEF	KPM-136	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 495
***Hygrophorus* sp 5**	KEF	KPM-162	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 496
***Hymenagaricus* sp 1**	KEF	KIC-54	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 497
***Hymenagaricus* sp 2**	KEF	KILR-86	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 498
***Hymenagaricus* sp 3**	KEF	KPGG-163	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 499
***Hymenagaricus* sp 4**	KEF	KIC-60	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 500
Hypholoma fasciculata	KEF	KIG-133	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 501
***Inocybe* sp 1**	KEF	KPG-153	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 502
***Inocybe* sp 3**	KEF	KPM-180	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 503
***Inocybe* sp 4**	KEF	KPG-167	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 504
***Inocybe* sp 2**	KEF	KPM-7	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 505
***Laccaria* sp 1**	KEF	KPG -145	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 506
***Laccaria* sp 3**	KEF	KPG -152	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 507
***Laccaria* sp 4**	KEF	KPGG-188	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 508
***Laccaria* sp 2**	KEF	KPG-158	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 509
Laccaria tortolis	KEF	KPM-173	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 510
Lacrymaria velutina	KEF	KIG-126	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 511
Lepiota felina	KEF	KIC29	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 512
***Lepiota* sp 1**	KEF	KIC-18	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 513
Lepista sordida	KEF	KIC013	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 514
***Leptonia* sp 1**	KEF	KIC-26	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 515
***Leptonia* sp 2**	KEF	KIC-28	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 516
***Leptonia* sp 3**	KEF	KIC-66	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 517
***Leptonia* sp 4**	KEF	KIG-125	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 518
***Leptonia* sp 5**	KEF	KIC-45	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 519
***Leucoagaricus* sp 1**	KEF	KPPG-195	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 520
***Leucoagaricus* sp 2**	KEF	KILR-23	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 521
***Leucocoprinus sp* 1**	KEF	KIG-128	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 522
***Leucocoprinus* sp 2**	KEF	KIL-41	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 523
***Leucopaxillus* sp**	KEF	KILR-69	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 524
Lycoperdon perlatum	KEF	KIC-8	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 525
Lycoperdon pyriforme	KEF	KIG-130	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 526
***Lycoperdon* sp 1**	KEF	KIC-39	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 527

Table 1 Continued.

Species	Locality	Code	Collectors	Voucher specimen
***Lycoperdon* sp 4**	KEF	KPM-24	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 528
***Lycoperdon* sp 5**	KEF	KPM-25	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 529
***Lycoperdon* sp 6**	KEF	KIC-50	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 530
***Lycoperdon* sp 2**	KEF	KIRL-33	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 531
***Lycoperdon* sp 3**	KEF	KPGG-210	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 532
Macrolepiota dolichaula	KEF	KPM -161	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 533
Macrolepiota procera	KEF	KPG-142	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 534
***Macrolepiota* sp 1**	KEF	KIC-018	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 535
Marasmius leucorotalis	KEF	KIG-132	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 536
***Marasmius* sp 1**	KEF	KIG-121	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 537
***Marasmius* sp 2**	KEF	KIG -103	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 538
***Marasmius* sp 3**	KEF	KPG-147	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 539
***Microporus* sp**	KEF	KIC-2	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 540
***Micropsalliota* sp 1**	KEF	KIC-23	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 541
***Micropsalliota* sp 2**	KEF	KPGG-188	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 542
***Mycena* sp 3**	KEF	KPM-139	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 543
Mycena* sp *4	KEF	KIG-103	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 544
***Mycena* sp 5**	KEF	KIG-105	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 545
***Mycena* sp 6**	KEF	KIG-115	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 546
***Mycena* sp 7**	KEF	KIG-123b	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 547
***Mycena* sp 8**	KEF	KPGG-189	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 548
***Mycena* sp 9**	KEF	KIG-129	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 549
Mycena* sp *10	KEF	KPPG-190	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 550
Mycena* sp *11	KEF	KIRL-66	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 551
***Myxomphalia* sp**	KEF	KIRL - 68	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 552
***Omphalia* sp**	KEF	KIC-13	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 553
Omphalina epichysum	KEF	KIC 011	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 554
***Panaeolina* sp 1**	KEF	KPM-140	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 555
***Panaeolina* sp 2**	KEF	KPPG-203	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 556
***Phaeocollybia* sp**	KEF	KPM-178b	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 557
***Phellinus* sp 1**	KEF	KIC-56	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 558
Phellinus gilvus	KEF	KIC-9	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 559
***Phellinus* sp 2**	KEF	KIG-115	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 560
***Phellinus* sp 4**	KEF	KIG- 67	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 561
***Phellinus* sp 3**	KEF	KILR-53	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 562
***Pholiota* sp 1**	KEF	KIG-100	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 563
***Pholiota* sp 2**	KEF	KIRL-94	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 564
Pholiota squarrosus	KEF	KIC-56	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 565
Pleurocybella porrigens	KEF	KIC-41	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 566
Pleurotus djamor	KEF	KIG-117	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 567
Pleurotus populinus	KEF	KIC-24	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 568
***Pleurotus* sp 1**	KEF	KILR-80	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 569
***Pleurotus* sp 2**	KEF	KIC-21	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 570
Fayodia leucophylla	KEF	KIC-57	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 571

Table 1 Continued.

Species	Locality	Code	Collectors	Voucher specimen
***Pleurotus* sp 3**	KEF	KPGG-185	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 572
***Pleurotus* sp 4**	KEF	KIG-112	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 573
***Pleurotus* sp 5**	KEF	KIG-101	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 574
***Pleurotus* sp 6**	KEF	KIRL-68	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 575
***Pluteus* sp**	KEF	KIG-113	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 576
***Polyporus* sp 1**	KEF	KIG-126	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 577
***Polyporus* sp 2**	KEF	KIG-140	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 578
***Polyporus* sp 3**	KEF	KPGG-151	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 579
***Polyporus* sp 4**	KEF	KIRL-69	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 580
***Polyporus* sp 5**	KEF	KILR-70	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 581
Psathyrella longipes	KEF	KIG-107	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 582
***Psathyrella* sp 1**	KEF	KIC-48	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 583
***Psathyrella* sp 2**	KEF	KILR-71	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 584
***Psathyrella* sp 3**	KEF	KIG-135	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 585
***Psathyrella* sp 4**	KEF	KPM-165	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 586
***Psathyrella* sp 5**	KEF	KILR-73	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 587
Pseudoclitocybe	KEF	KPM-178b	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 588
***Psilocybe* sp 1**	KEF	KIRL-83	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 589
***Psilocybe* sp 2**	KEF	KIG-114	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 590
***Resinomycena* sp 3**	KEF	KIC-42	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 591
***Roridomyces* sp 1**	KEF	KIC-47	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 592
***Roridomyces* sp 3**	KEF	KIC -38	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 593
***Roridomyces* sp 4**	KEF	KIG-97	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 594
***Roridomyces* sp 5**	KEF	KIC-29	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 595
***Roridomyces* sp 6**	KEF	KIG-73	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 596
***Roridomyces* sp 7**	KEF	KPPG-155	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 597
***Spongillipellis* sp 4**	KEF	KIL-77	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 598
***Spongipellis* sp 1**	KEF	KIL-85	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 599
***Spongipellis* sp 1**	KEF	KIL-86	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 600
Spongipellis* sp *3	KEF	KIC-8	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 601
Stereum gausapatum	KEF	KIG-110	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 602
Stereum ostrea	KEF	KIC-42	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 603
Stropharia rugosoannulata	KEF	KIC- 1	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 604
***Stropharia* sp 1**	KEF	KPG-148	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 605
Stropharia* sp *3	KEF	KPGG-190	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 606
***Stropharia* sp 2**	KEF	KPG-170	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 607
Suillus granulatus	KEF	KPM -144	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 608
Suillus lutea	KEF	KPM-143	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 609
***Suillus* sp 1**	KEF	KPPG-003	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 610
***Trametes* sp**	KEF	KIL-188	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 611
***Trichaptum* sp**	KEF	KIG-108	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 612
Tricholomopsis rutilans	KEF	KIC-50	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 613
***Tricholomopsis* sp 1**	KEF	KIC- 12	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 614

Table 1 Continued.

Species	Locality	Code	Collectors	Voucher specimen
***Trogia* sp 1**	KEF	KIC-52	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 615
***Trogia* sp 3**	KEF	KIC-17	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 616
***Trogia* sp 2**	KEF	KIC-11	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 617
***Typhula* sp**	KEF	KIC-51	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 618
Vascellum pratense	KEF	KPG-44	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 619
***Xeromphalia* sp 1**	KEF	KIC-40	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 620
***Xeromphalina* sp 2**	KEF	KIC-65	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 621
***Xeromphalina* sp 3**	KEF	KIC-60	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 622
Xerula radicata	KEF	KLR-79	Njuguini, Nyawira, Muchai, Saado & Kamau	NMKEA 623

Fig. 1 – Some macrofungi species collected during dry season and wet season in plantation and indigenous forest in Kereita forest. Key: 1 *Macrolepiota dolichaula.* 2 *Suillus lutea.* 3 *Daldinia concentrica.* 4 *Favolaschia calocera.* 5 *Trametes versicolor.* 6 *Cyathus striatus.* 7 *Stereum ostrea.* 8 *Crepidotus variabilis.* 9 *Agaricus inoxydabilis.* 10 *Auricularia delicate.* 11 *Coprinellus disseminates.* 12 *Cytoderma elegans.*

Identification of the specimens

The study used both macro and micro -morphological characterization to identify macrofungi species found in natural and plantation forests. Identification of the macrofungi was based on both macroscopic and microscopic features (Mueller et al. 2005, Prakasam 2012, Senthilarasu 2014). The information of the various characteristics was used to identify each specimen by making comparison with illustrations in colour field guides and descriptions. We used varieties of field monograph of coloured mushrooms keys and books (Ryvarden et al. 1994, Weithuizen & Eicker 1994, Härkönen et al. 2003, Phillips 2006, McAdam 2009) as well as Internet-based scientific literature search engine. The macroscopic features ranged from the cap appearance and size, colour, shape, surface texture and surface moisture, gill attachment, gill colour, gill spacing, lamellules, the stem size and attachment, shape, surface texture and surface moisture, presence or absence of partial and universal veils, flesh colour and texture, stem base morphology, habitat/substrate. Microscopic features were carried out using standard microscopic methods (Senthilarasu 2014). The Edinburgh Botanic Gardens colour chart was used for the description of specimens and spore print colours. The dried specimen were revived in 10% KOH in order to study further details, Meltzer reagent and cresyl blue were used to study the spores amyloidity and metachromic reactions respectively.

Data analysis

The macrofungi frequency of occurrence was calculated as total number of individuals per group over total number of all the groups multiplied by 100 (Wang & Jiang 2015). The macrofungi species densities were calculated as total numbers of a species per unit area ($1m^2$) (Feest 2006). Species richness was calculated as total number of species per 20 by 20m plot. Species Shannon–Wiener diversity index (H´) and Simpson index were calculated for each field plot using PAST programme (Hammer et al. 2001). Simpson's diversity index (D) was calculated according to Megersa et al. (2016) where $D=\Sigma Pi^2$ …Pi = Ni / N, and Ni = Σ Ni and Shannon-Wiener index as (H'= Σ [pi (log pi)], where; pi is the proportion of individuals found in species; ln is the natural logarithm) (Margalef 2008). Two-way ANOVA was performed to assess the effects of forest type and season on species richness, density and diversity measures. Differences between treatment means were separated by Turkey's *post hoc* test at $P < 0.05$. The effects of forest type and seasonality on macrofungi community composition were analysed by a multivariate redundancy analysis (RDA) using the Conoco 4.5 software (ter Braak & Smilauer 1998). All data were tested for normality, and where necessary count data were logarithm, (log+1) transformed to ensure conformity of the data with ANOVA assumptions.

Results

Macrofungi community within Kereita forest

A total number of 28 families, 76 genera and 224 species distributed in the division Basidiomycota (223 genera within 27 families) and Ascomycota (1) species in the family Xylariaceae were encountered (Table 2). In the division Basidiomycota, the macrofungi species majorly belonged to the class Agaricomycetes represented by 28 families and class Sordariomycetes represented by only 1 family (Xylariaceae). In the class Agaricomycetes, the order Agaricales (69%) represented the highest proportion of families followed by polyporales (14%). The family representation in other orders (Auriculariales, Haemenochaetales, Phallales and Xylariales) was at 3% each. Overall, the Agaricaceae family had the highest number of genera (13), followed by Tricholomataceae (7), Polyporaceae (7), Mycenaceae (6) and majority of the families (18) represented 1 genus each. Certain species belonging to the following families; Crepidotaceae, Physalacriaceae, Funariaceae, Gomphidiaceae, Meruliaceae, Niduliaceae, Pluteaceae, Typhulaceae and Xylariaceae were noted only in the indigenous forest (Fig. 2). The plantation also had species from 4 families (Hydnangiaceae, Inocybaceae, Gomphidiaceae and Suillaceae) not encountered in indigenous forest (Fig. 2). The rest of the species were found occurring in both forest types (Figs 2, 5). Approximately 24% of the specimens were identified to species level, while 76 % were classified as a morphospecies belonging to some genus (Table 2). Species accumulation curve showing the number of macrofungi species encountered within the two forest types did not reach an asymptote (Fig. 3).

Table 2 Checklist of Macrofungi species in Kereita forests block of Kikuyu Escarpment forest

			Pine Plantation		Indigenous	
Families	**Species**	**Substrates**	**Wet**	**Dry**	**Wet**	**Dry**
Mycenaceae	*Mycena inclinata*	Wood	+	_	_	_
Mycenaceae	*Mycena* sp 2	Wood	+	_	_	_
Agaricaceae	*Agaricus augustus*	Soil	+	_	_	_
Agaricaceae	*Agaricus inoxydabilis*	Soil	+	_	_	_
Agaricaceae	*Agaricus silvaticus*	Soil	+	_	_	_
Agaricaceae	*Agaricus* sp 3	Soil	_	_	+	_
Agaricaceae	*Agaricus* sp 5	Soil	+	_	_	_
Agaricaceae	*Agaricus* sp 7	Soil	_	_	_	+
Strophariaceae	*Agrocybe* sp 1	Litter	_	_	_	+
Strophariaceae	*Agrocybe* sp 2	Litter	_	_	_	+
Physalacriaceae	*Armillaria mellea*	Parasitic	+	_	_	_
Physalacriaceae	*Armillaria* sp 1	Parasitic	+	_	_	_
Physalacriaceae	*Armillaria* sp 2	Parasitic	+	_	_	_
Auriculariacea	*Auricalaria auricula*	Wood	+	_	_	_
Auriculariacea	*Auricalaria delicata*	Wood	+	_	_	_
Auriculariacea	*Auricalaria polytrica*	Wood	+	_	_	_
Bolbitiaceae	*Bolbitius* sp 1	Litter	+	_	_	_
Bolbitiaceae	*Bolbitius* sp 2	Litter	+	_	_	_
Bolbitiaceae	*Bolbitius* sp 3	Litter	_	_	_	+
Bolbitiaceae	*Bolbitius* sp 4	Litter	_	_	_	+
Pluteaceae	*Chamaeota* sp	Wood	+	_	_	_
Gomphidiaceae	*Chroogomphus* sp 1	Ectomycorrhizal	_	_	+	_
Gomphidiaceae	*Chroogomphus* sp 2	Ectomycorrhizal	_	_	+	_
Gomphidiaceae	*Chroogomphus* sp 3	Ectomycorrhizal	_	_	+	_
Agaricaceae	*Clavatia* sp 1	Litter	_	_	+	_
Tricholomataceae	*Clavatia* sp 2	Litter	_	_	+	_
Tricholomataceae	*Clavatia* sp 3	Litter	_	_	+	_
Tricholomataceae	*Clitocybe dilitata*	Soil	+	_	_	_
Tricholomataceae	*Clitocybe* sp 1	Soil	+	_	_	_
Tricholomataceae	*Clitocybe* sp 2	Soil	+	_	_	_
Tricholomataceae	*Clitocybe* sp 3	Soil	+	_	_	_
Tricholomataceae	*Clitopilus* sp 1	Litter	+	_	_	_
Tricholomataceae	*Clitopilus* sp 2	Litter	+	_	+	_
Bolbitiaceae	*Conocybe* sp *1*	Litter	_	_	+	_
Bolbitiaceae	*Conocybe tenera*	Litter	_	_	+	_
Agaricaceae	*Coprinus comatus*	Litter	+	_	_	_
Agaricaceae	*Coprinus disseminatus*	Litter	+	_	_	_
Agaricaceae	*Coprinus jonesii*	Litter	_	_	+	_
Agaricaceae	*Coprinus* sp 1	soil	+	_	_	_
Agaricaceae	*Coprinus* sp 2	Litter	+	_	_	_
Agaricaceae	*Coprinus* sp 3	Litter	+	_	_	_
Agaricaceae	*Coprinus stercoreus*	Litter	+	_	_	_
Crepidotaceae	*Crepidotus applanatus*	Wood	_	+	_	_
Crepidotaceae	*Crepidotus* sp 1	Wood	+	_	_	_

Table 2 Continued.

			Pine Plantation		Indigenous	
Families	**Species**	**Substrates**	**Wet**	**Dry**	**Wet**	**Dry**
Crepidotaceae	*Crepidotus* sp 2	Wood	+	_	_	_
Crepidotaceae	*Crepidotus* sp 3	Wood	+	_	_	_
Nidulariaceae	*Cyathus poeppigii*	Wood	+	_	_	_
Nidulariaceae	*Cyathus striatus*	Wood	+	_	+	_
Meruliaceae	*Cymatoderma elegance*	Wood	+	_	_	_
Physalacriaceae	*Cyptotrama* sp	Wood	+	_	_	_
Agaricaceae	*Cystolepiota* sp 1	Soil	+	_	_	_
Agaricaceae	*Cystolepiota* sp 2	Soil	+	_	_	_
Agaricaceae	*Cystolepiota* sp 3	Soil	+	_	_	_
Agaricaceae	*Cystolepiota* sp 4	Soil	+	_	_	_
Agaricaceae	*Cystolepiota* sp 5	Soil	+	_	_	_
Agaricaceae	*Cystolepiota* sp 6	Soil	+	_	+	_
Agaricaceae	*Cystolepiota* sp 7	Soil	+	_	_	_
Agaricaceae	*Cytolepiota* sp 8	Soil	+	_	_	_
Agaricaceae	*Cytolepiota* sp 9	Soil	+	_	_	_
Xylariaceae	*Daldinia concentrica*	Wood	_	+	_	_
Entolomataceae	*Entoloma* sp 1	Soil	+	_	_	_
Entolomataceae	*Entoloma* sp 2	Litter	+	_	_	_
Entolomataceae	*Entoloma* sp 3	Litter	+	_	+	_
Mycenaceae	*Favolaschia calocera*	Wood	+	+	_	_
Mycenaceae	*Favolaschia cyathea*	Wood	_	+	_	_
Tricholomataceae	*Fayodia leucophylla*	Wood	_	+	_	_
Polyporaceae	*Fomentarius fomes*	Wood	_	+	_	_
Funariaceae	*Funaria* sp	Wood	+	_	_	_
Hymenogastraceae	*Galerina* sp 1	Wood	+	_	_	_
Hymenogastraceae	*Galerina* sp 2	Wood	+	_	_	_
Hymenogastraceae	*Ganoderma applanatum*	Parasitic	_	+	_	_
Ganodermataceae	*Ganoderma australe*	Parasitic	_	_	+	_
Ganodermataceae	*Ganoderma* sp	Parasitic	_	+	_	_
Hygrophoraceae	*Gliophorus* sp 1	Litter	+	_	_	_
Hygrophoraceae	*Gliophorus* sp 2	Litter	+	_	_	_
Hygrophoraceae	*Gliophorus* sp 3	Litter	+	_	_	_
Marasmiaceae	*Gymnopus* sp 1	Wood	+	_	_	_
Marasmiaceae	*Gymnopus* sp 2	Wood	+	_	_	_
Marasmiaceae	*Gymnopus* sp 3	Wood	+	_	_	_
Marasmiaceae	*Gymnopus* sp 4	Wood	+	_	_	_
Marasmiaceae	*Gymnopus* sp 5	Wood	+	_	_	_
Marasmiaceae	*Gymnopus* sp 6	Wood	+	_	_	_
Marasmiaceae	*Gymnopus* sp 7	Wood	+	_	_	_
Marasmiaceae	*Gymnopus subpruinosus*	Wood	+	_	_	_
Agaricaceae	*Handkea* sp	Soil	+	_	_	_
Mycenaceae	*Hemimycena* sp	Wood	_	+	_	_
Polyporaceae	*Hexagonia* sp 1	Wood	_	+	_	_
Polyporaceae	*Hexagonia* sp 2	Wood	_	+	_	_

Table 2 Continued.

			Pine Plantation		Indigenous	
Families	**Species**	**Substrates**	**Wet**	**Dry**	**Wet**	**Dry**
Polyporaceae	*Hexagonia tenuis*	Wood	_	+	_	_
Hygrophoraceae	*Hygrocybe conica*	Soil	_	_	+	_
Hygrophoraceae	*Hygrocybe persistens*	Soil	+	_	_	_
Hygrophoraceae	*Hygrophorus* sp 1	Litter	_	_	+	_
Hygrophoraceae	*Hygrophorus* sp 4	Litter	+	_	_	_
Hygrophoraceae	*Hygrophorus* sp 2	Litter	_	_	+	_
Hygrophoraceae	*Hygrophorus* sp 3	Litter	_	_	+	_
Hygrophoraceae	*Hygrophorus* sp 5	Litter	_	+	_	_
Agaricaceae	*Hymenagaricus* sp 1	Litter	+	_	_	_
Agaricaceae	*Hymenagaricus* sp 2	Litter	_	_	+	_
Agaricaceae	*Hymenagaricus* sp 3	Litter	+	_	_	_
Agaricaceae	*Hymenagaricus* sp 4	Litter	_	+	_	_
Strophariaceae	*Hypholoma fasciculata*	Wood	+	+	_	_
Inocybaceae	*Inocybe* sp 1	Ectomycorrhizal	_	_	+	_
Inocybaceae	*Inocybe* sp 3	Ectomycorrhizal	_	_	+	_
Inocybaceae	*Inocybe* sp 4	Ectomycorrhizal	_	_	_	+
Inocybaceae	*Inocybe* sp 2	Ectomycorrhizal	_	_	+	_
Hydnangiaceae	*Laccaria* sp 1	Ectomycorrhizal	_	_	+	_
Hydnangiaceae	*Laccaria* sp 3	Ectomycorrhizal	_	_	+	_
Hydnangiaceae	*Laccaria* sp 4	Ectomycorrhizal	_	_	+	_
Hydnangiaceae	*Laccaria* sp 2	Ectomycorrhizal	_	_	+	_
Hydnangiaceae	*Laccaria tortolis*	Ectomycorrhizal	_	_	+	+
Psathyrellaceae	*Lacrymaria velutina*	Wood	_	+	_	_
Agaricaceae	*Lepiota felina*	Litter	+	_	_	_
Agaricaceae	*Lepiota* sp 1	Soil	+	_	_	+
Tricholomataceae	*Lepista sordida*	Litter	+	_	_	_
Entolomataceae	*Leptonia* sp 1	Litter	+	_	_	_
Entolomataceae	*Leptonia* sp 2	Litter	+	+	_	_
Entolomataceae	*Leptonia* sp 3	Litter	+	_	_	_
Entolomataceae	*Leptonia* sp 4	Litter	+	+	_	_
Entolomataceae	*Leptonia* sp 5	Litter	+	_	_	_
Agaricaceae	*Leucoagaricus* sp 1	Soil	_	_	+	+
Agaricaceae	*Leucoagaricus* sp 2	Soil	_	+	_	_
Agaricaceae	*Leucocoprinus sp* 1	Litter	+	_	_	_
Agaricaceae	*Leucocoprinus* sp 2	Litter	+	_	_	_
Agaricaceae	*Leucopaxillus* sp	Litter	+	_	_	_
Lycoperdaceae	*Lycoperdon perlatum*	Soil	_	_	_	+
Lycoperdaceae	*Lycoperdon pyriforme*	Soil	_	_	_	+
Lycoperdaceae	*Lycoperdon* sp 1	Soil	_	_	+	_
Lycoperdaceae	*Lycoperdon* sp 4	Soil	_	_	+	_
Lycoperdaceae	*Lycoperdon* sp 5	Soil	+	_	_	_
Lycoperdaceae	*Lycoperdon* sp 6	Soil	_	_	_	+
Lycoperdaceae	*Lycoperdon* sp 2	Soil	+	_	_	_
Lycoperdaceae	*Lycoperdon* sp 3	Soil	_	_	+	_

Table 2 Continued.

			Pine Plantation		Indigenous	
Families	**Species**	**Substrates**	**Wet**	**Dry**	**Wet**	**Dry**
Agaricaceae	*Macrolepiota dolichaula*	Litter	_	_	+	_
Agaricaceae	*Macrolepiota procera*	Litter	+	_	+	+
Agaricaceae	*Macrolepiota* sp 1	Litter	+	_	_	_
Marasmiaceae	*Marasmius leucorotalis*	Litter	_	_	+	_
Marasmiaceae	*Marasmius* sp 1	Litter	_	_	+	_
Marasmiaceae	*Marasmius* sp 2	Litter	+	_	_	_
Marasmiaceae	*Marasmius* sp 3	Litter	+	_	_	_
Polyporaceae	*Microporus* sp	Wood	_	+	_	_
Polyporaceae	*Micropsalliota* sp 1	litter	+	_	_	_
Polyporaceae	*Micropsalliota* sp 2	litter	+	_	_	_
Mycenaceae	*Mycena* sp 1	Litter	+	_	_	_
Mycenaceae	*Mycena* sp 2	Litter	+	_	_	_
Mycenaceae	*Mycena* sp 4	Litter	+	_	_	_
Mycenaceae	*Mycena* sp 5	Litter	+	_	_	_
Mycenaceae	*Mycena* sp 8	wood	+	_	_	_
Mycenaceae	*Mycena* sp 9	Litter	+	_	_	_
Mycenaceae	*Mycena* sp 3	Wood	+	_	_	_
Mycenaceae	*Mycena* sp 6	Litter	+	_	_	_
Mycenaceae	*Mycena* sp *7*	Litter	+	_	_	_
Tricholomataceae	*Myxomphalia* sp	Litter	+	_	_	_
Tricholomataceae	*Omphalia* sp	Litter	+	+	_	_
Tricholomataceae	*Omphalina epichysum*	Litter	+	_	_	_
Bolbitiaceae	*Panaeolina* sp 1	litter	_	_	_	+
Bolbitiaceae	*Panaeolina* sp 2	litter	_	_	_	+
Hymenogastraceae	*Phaeocollybia* sp	Saprophytic	_	+	_	_
Polyporaceae	*Phellinus* sp 1	Parasitic	_	+	_	_
Polyporaceae	*Phellinus gilvus*	Parasitic	_	+	_	_
Polyporaceae	*Phellinus* sp 2	wood	_	_	_	+
Polyporaceae	*Phellinus* sp 3	wood	_	_	_	+
Polyporaceae	*Phellinus* sp 4	wood	_	_	_	+
Strophariaceae	*Pholiota* sp 1	Wood	+	_	_	_
Strophariaceae	*Pholiota* sp 2	Wood	+	_	_	_
Strophariaceae	*Pholiota squarrosus*	Wood	+	_	_	_
Pleurotaceae	*Pleurocybella porrigens*	Wood	+	_	_	_
Pleurotaceae	*Pleurotus djamor*	Wood	_	+	_	_
Pleurotaceae	*Pleurotus populinus*	Wood	+	_	_	_
Pleurotaceae	*Pleurotus* sp 1	Wood	+	_	_	_
Pleurotaceae	*Pleurotus* sp 2	Wood	+	_	_	_
Tricholomataceae	*Fayodia leucophylla*	Wood	+	_	_	_
Pleurotaceae	*Pleurotus* sp 3	Wood	+	_	+	_
Pleurotaceae	*Pleurotus* sp 4	Wood	+	_	_	_
Pleurotaceae	*Pleurotus* sp 5	Wood	+	_	_	_
Pleurotaceae	*Pleurotus* sp 6	Wood	+	_	_	_
Plutaceae	*Pluteus* sp	Wood	+	_	_	_

Table 2 Continued.

			Pine Plantation		Indigenous	
Families	**Species**	**Substrates**	**Wet**	**Dry**	**Wet**	**Dry**
Polyporaceae	*Polyporus* sp 1	Wood	+	_	_	_
Polyporaceae	*Polyporus* sp 2	Wood	+	_	_	_
Polyporaceae	*Polyporus* sp 3	Wood	+	_	_	_
Polyporaceae	*Polyporus* sp 4	Wood	+	_	_	_
Polyporaceae	*Polyporus* sp 5	Wood	_	+	_	_
Psathyrellaceae	*Psathyrella longipes*	Litter	+	+	_	_
Psathyrellaceae	*Psathyrella* sp 1	Wood	+	_	_	_
Psathyrellaceae	*Psathyrella* sp 2	Litter	+	_	_	_
Psathyrellaceae	*Psathyrella* sp 3	Litter	+	_	_	_
Psathyrellaceae	*Psathyrella* sp 4	Litter	+	_	+	_
Psathyrellaceae	*Psathyrella* sp 5	Litter	+	_	+	_
Tricholomataceae	*Pseudoclitocybe*	Ectomycorrhizal	_	_	+	_
Hymenogastraceae	*Psilocybe* sp 1	Wood	_	_	+	_
Hymenogastraceae	*Psilocybe* sp 2	Wood	_	_	+	_
Marasmiaceae	*Resinomycena* sp	Wood	_	+	_	_
Mycenaceae	*Roridomyces* sp 1	Wood	+	_	_	_
Mycenaceae	*Roridomyces* sp 2	Wood	+	_	_	_
Mycenaceae	*Roridomyces* sp 3	Wood	+	_	_	_
Mycenaceae	*Roridomyces* sp 4	Wood	+	_	_	_
Mycenaceae	*Roridomyces* sp 5	Wood	+	_	_	_
Mycenaceae	*Roridomyces* sp 6	Wood	+	_	_	_
Polyporaceae	*Spongillipellis* sp 1	Wood	_	_	+	_
Polyporaceae	*Spongipellis* sp 2	Wood	_	+	_	_
Polyporaceae	*Spongipellis* sp 3	Wood	_	+	_	_
Polyporaceae	*Spongipellis* sp *4*	Wood	_	+	_	_
Polyporaceae	*Stereum gausapatum*	Wood	+	_	_	_
Stereaceae	*Stereum ostrea*	Wood	_	_	+	_
Strophariaceae	*stropharia rugosoannulata*	Litter	_	_	_	+
Strophariaceae	*Stropharia* sp 1	Litter	_	_	+	_
Strophariaceae	*Stropharia* sp 3	Litter	+	_	_	_
Strophariaceae	*Stropharia* sp 2	Litter	_	_	+	_
Tricholomataceae	*Suillus granulatus*	Ectomycorrhizal	_	_	_	+
Suillaceae	*Suillus lutea*	Ectomycorrhizal	_	_	_	+
Suillaceae	*Suillus* sp 1	Ectomycorrhizal	_	_	+	+
Polyporaceae	*Trametes* sp	Wood	_	+	_	_
Polyporaceae	*Trichaptum* sp	Wood	_	+	_	_
Tricholomataceae	*Tricholomopsis rutilans*	Wood	+	_	_	_
Marasmiaceae	*Tricholomopsis* sp 1	Wood	+	_	_	_
Marasmiaceae	*Trogia* sp 1	Wood	+	_	_	_
Marasmiaceae	*Trogia* sp 3	Wood	+	_	_	_
Marasmiaceae	*Trogia* sp 2	Wood	+	_	_	_
Lycoperdaceae	*Typhula* sp	Litter	_	+	+	_
Physalacriaceae	*Vascellum pratense*	Soil	_	_	_	_
Marasmiaceae	*Xeromphalia* sp 1	Litter	+	_	_	_

Table 2 Continued.

			Pine Plantation		Indigenous	
Families	**Species**	**Substrates**	**Wet**	**Dry**	**Wet**	**Dry**
Marasmiaceae	*Xeromphalina* sp 2	Litter	_	+	_	_
Typhulaceae	*Xeromphalina* sp 3	Litter	_	+	_	_
Physalacriaceae	*Xerula radicata*	Wood	+	-_	_	_

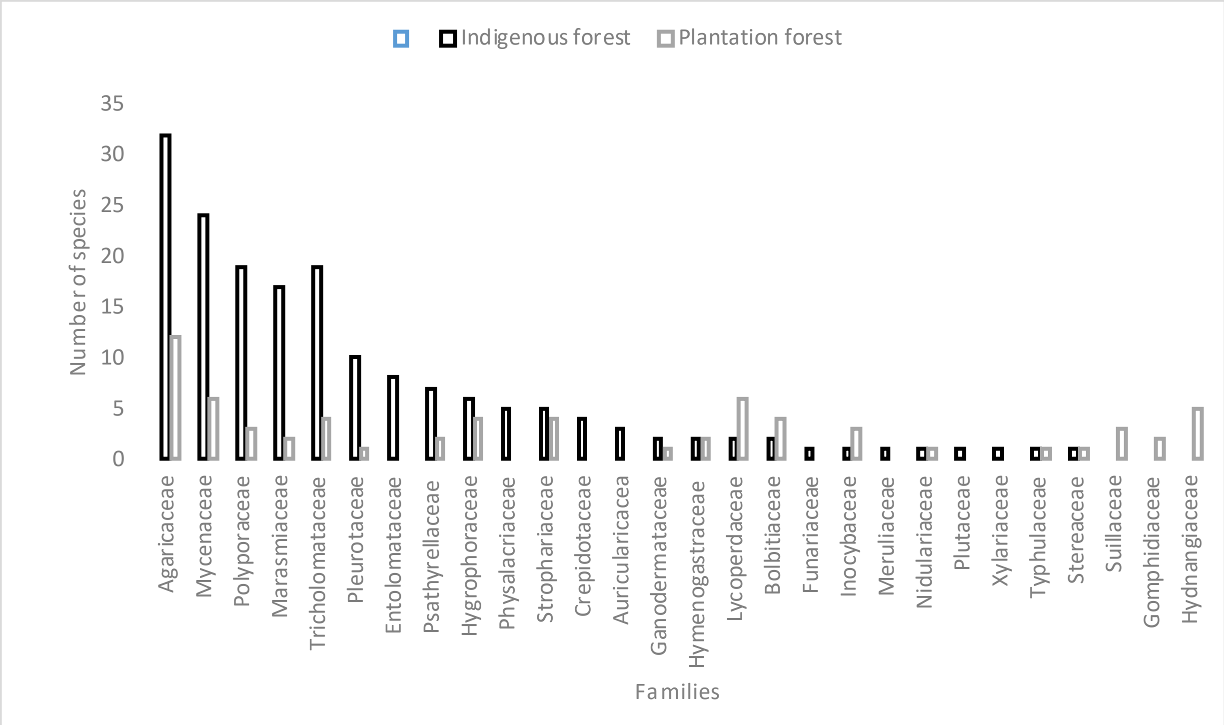

Fig. 2 – Distribution of Macrofungi families in the indigenous and plantation forest within Kereita forest.

Fig. 3 – Species of macrofungi sampled in Kereita forest during the dry and wet season in the indigenous and plantation forest

Distribution of macrofungi in different biotrophic groups

The macrofungi were placed in three different biotrophic groups based on their nature of utilizing substrates to determine their distribution during the wet and dry seasons in the indigenous and pine plantation. The first group belonged to the saprotrophic species potentially colonizing litter, soil organic matter and wood based substrates. The second group represented the ectomycorrhiza fungi known to form symbiotic association with plant roots. The third group comprised of the parasitic macrofungi known to colonise dead or living trees. The wet season was characterized by high number of the saprophytic fungi with 93% (Wood rotters 35%, litter decomposers 41% and soil dwellers 17%), compared to the dry season with 89% (wood rotters 37%, litter decomposers 41 % and soil dwellers 11%) decomposers (Fig. 4).The ectomycorrhiza and parasitic group were less than 10% each during the two seasons. Saprotrophic fungi (litter, soil and wood decomposers) were majority under the two forest types representing 90% of total species, followed by ectomycorhiza (symbionts) and parasitic macrofungi each representing 10% of the total macrofungi species in both forest types (Fig. 4). Saprophytic species were dominant in the indigenous forest during the dry and wet season and were represented by wood rotters (50%), litter decomposers (29%) and soil (organic matter) colonizers (16%) (Fig. 4). Pine plantation was dominated by both saprophytic and ectomycorrhiza species. Ectomycorrhiza species occurred only in the pine plantation forest and represented 6% of the total functional groups.

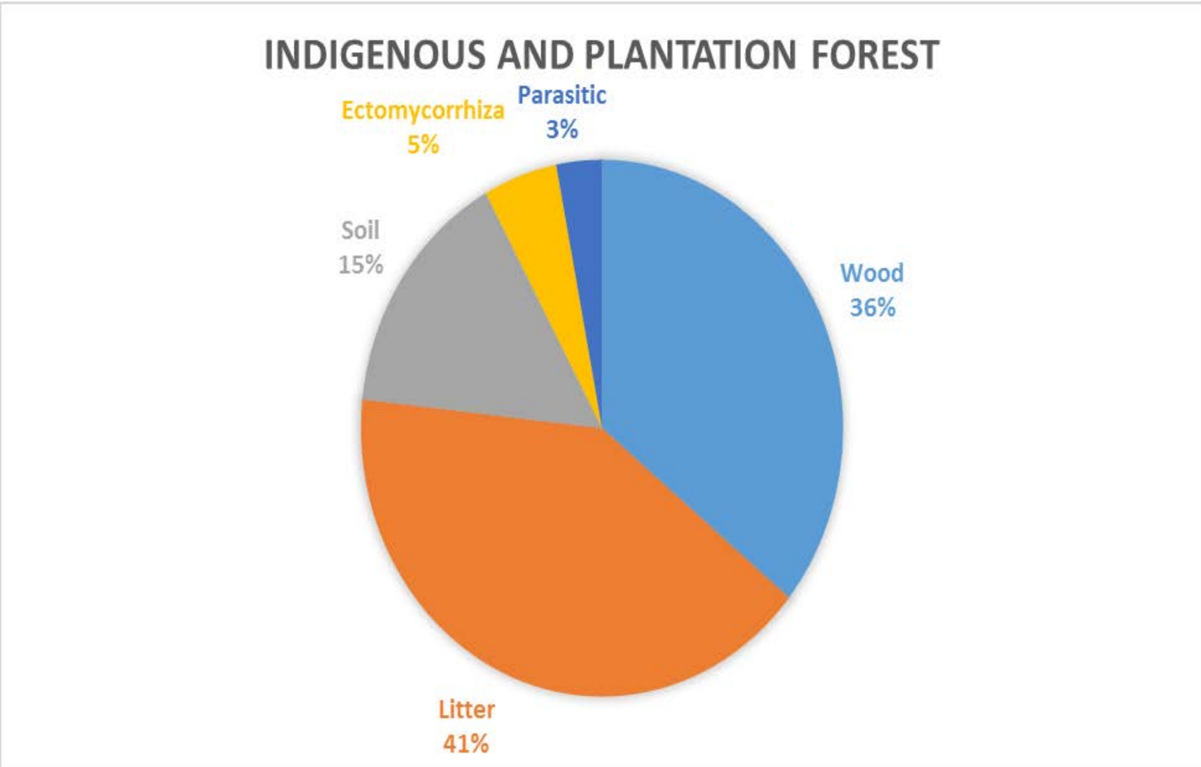

Fig. 4 – Distribution of macrofungi by biotrophic groups in the indigenous and plantation forest during the wet and dry season, Kereita forest

Species composition

Macrofungi community composition in the Kereita forest was significantly affected by forest type (RDA, $F = 5.47$, $P < 0.05$), which explained respectively 9% of the variability in the dataset (Fig. 5). Conversion of indigenous forest to pine plantation forest significantly ($p<0.05$) reduced density of both saprophytic macrofungi genera such as *Armillaria*, *Pleurocybella*, *Cyathus* and *Galerina* (Fig. 6) and parasitic species such as *Microporus*, *Phellinus* and *Trametes* (Fig. 7) by more than 10% (Fig. 5). The ectomycorrhiza species previously not in indigenous forest especially species belonging to *Suillus* and *Laccaria* were introduced in pine plantation and made up 14%

macrofungi community in Kereita forest (Fig. 8).The macrofungi species composition (community) was also significantly affected by seasonality (RDA, F = 3.97, P < 0.05) which explained 6% of the variability. The wet season was characterized by high number of fleshy wood rooting macrofungi species, which belong to *Pleurocybella*, *Cyathus*, *Hygrocybe*, A*rmillaria*, *Favolaschia*, *Myxomphalia*, *Micropsalliota* occurring in the indigenous forest only (Fig. 5). However, the polypores such as *Trametes*, *Microporus* and *Phellinus*, were present during the dry and the wet season in both land use types (Fig.7). The genus *Agaricus* appeared in both land use types during the dry and wet season (Fig. 9). Therefore, seasonality and land use type was shown to have an effect on the community of macrofungi in Kereita forest.

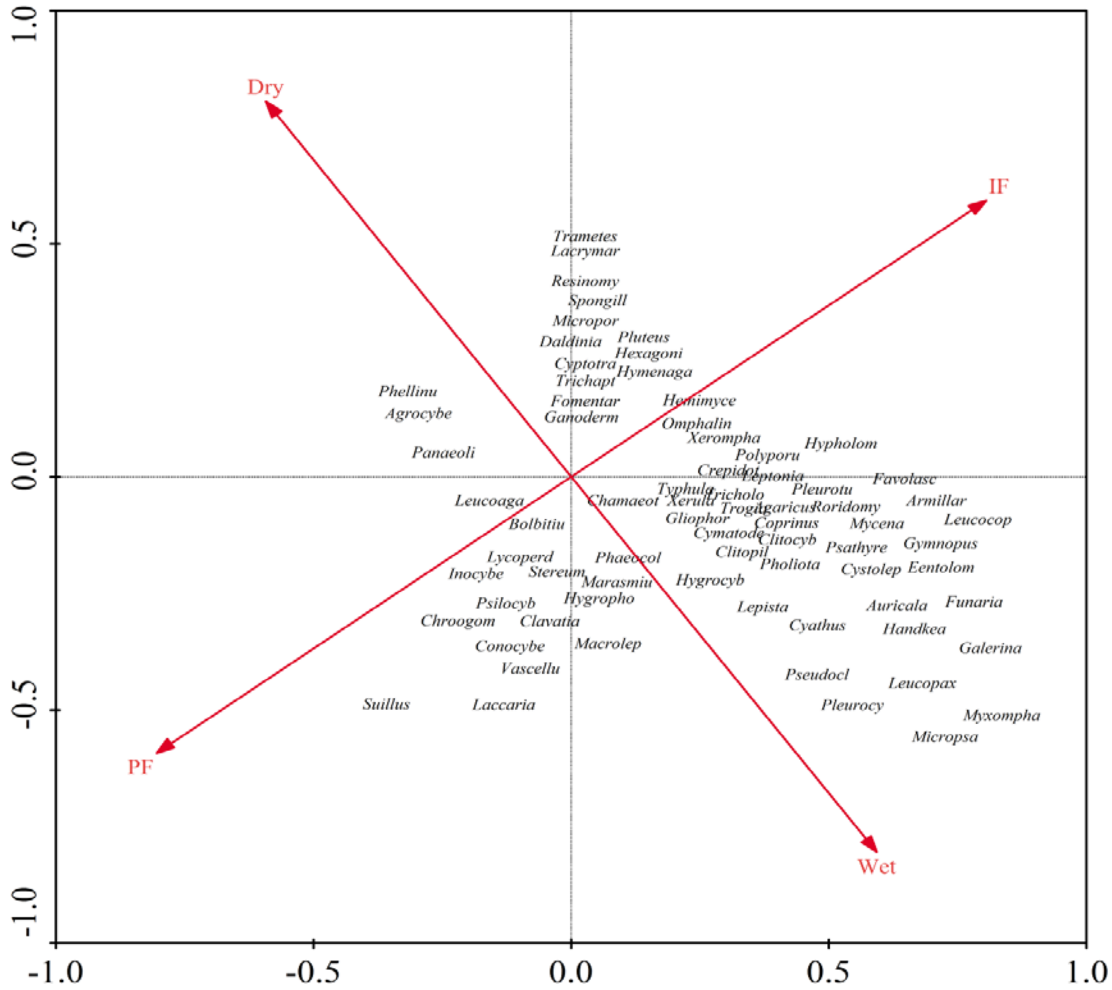

Fig. 5 – Redundancy analysis (RDA) on the species composition of macrofungi in Kerita forest during the dry and wet season. Armillal-*Armillaria*, Auricala-*Auricularia*, Bolbitiu-*Bolbitus*, Chamaeot-*Chamaeta*, Chroogom-*Chroogomphus*, Clitopil-*Clitopilus*, Cymatode- *Cymatoderma*, Cyptotra- *Cyptotrama* , Cytolep-*Cytolepiota* , Eentolom-*Entoloma*, Favolasc-*Favolaschia*, Fomentar-*Fomentarius*, Ganoderm-*Ganoderma*, Gliophor-*Gliophorus*, Hexagoni-*Hexagonia*, Hygrocyb-*Hygrocybe*,Hygropho-*Hygrophorus*, Hymenag-*Hymenaagaricus*, Hypholom-*Hypholoma*, Lacrymar-*Lacrymaria*, Leucoaga-*Leucoagaricus* , Leucocop-*Leucocoprinus*, Leucopax-*Leucopaxillus*, Leucoperd-*Leucoperdon*, Macrolep-*Macrolepiota*, Marasmiu-*Marasmius*, Micropor-*Microporus*, Micropsa-*Micropsaliota*, Omphalin-*Omphalina* , Panaeoli-*Panaeolus* , Phaeocol *Phaeocollybia*, Phellinu-*Phellinus* , Pleurotu-*Pleurotus*, Psathyre-*Psathyrella*, Pseudocl-*Pseudoclitocybe*, Psilocy-*Psilocybe*, Resinomy-*Resinomyce*, Roridomy-*Roridomycena* , Spongill-*Spongilipellis*, Trichapt-*Trichaptam*, Trichol-*Tricholoma*, Vascellu-*Vascellum* , Xerompha-*Xeromphalina*

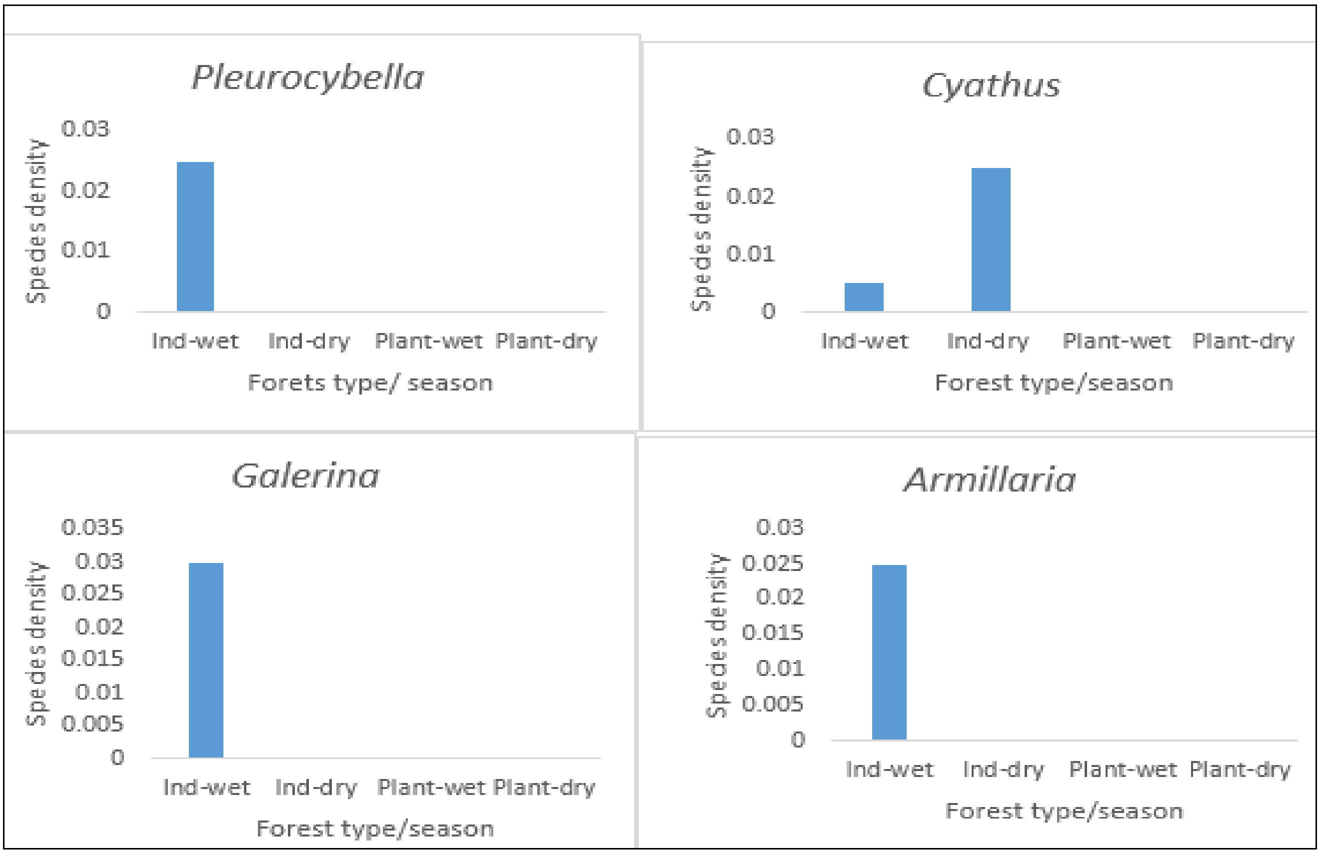

Fig. 6 – Fleshy wood rotting macrofungi in the indigenous forest during the wet and the dry season

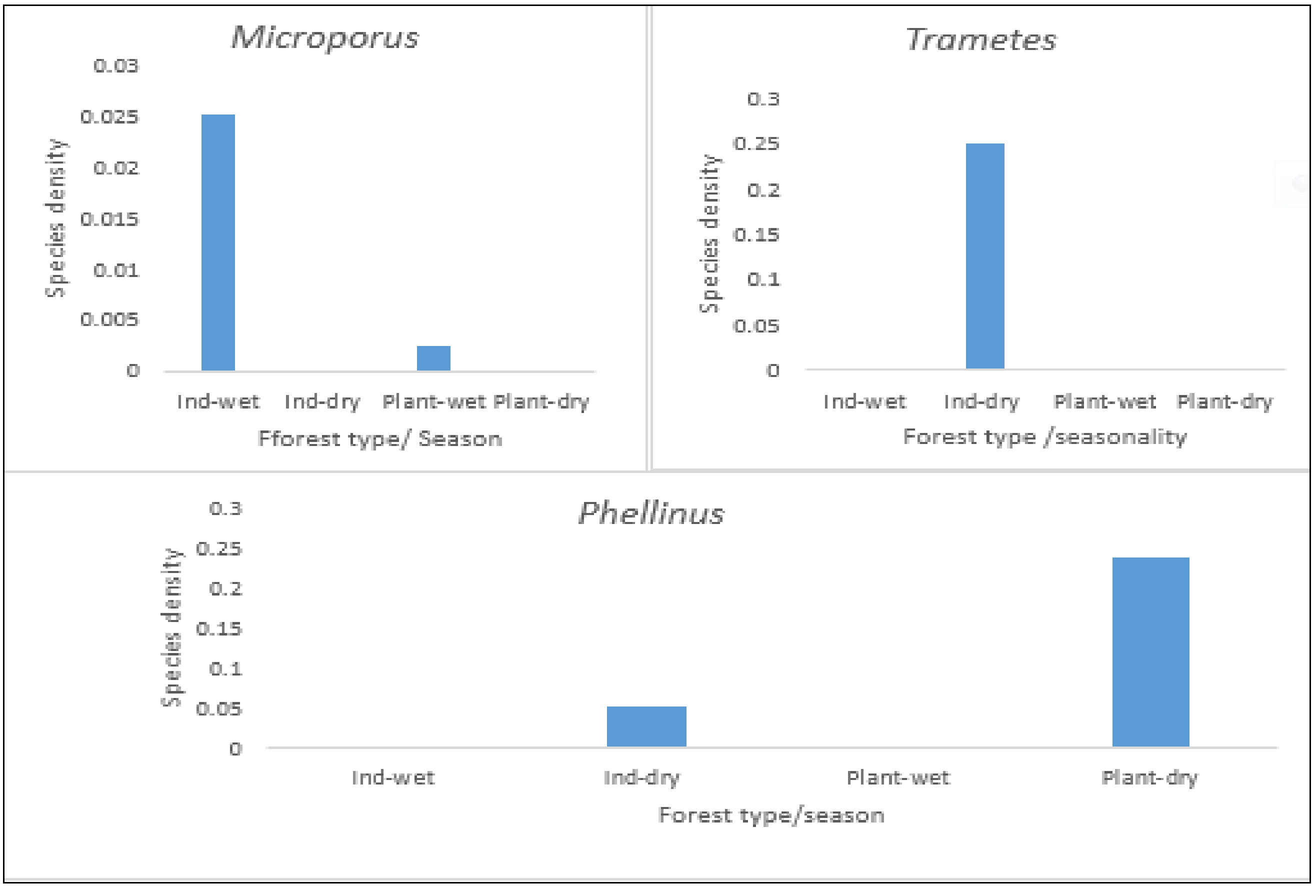

Fig. 7 – Polypores in the indigenous and plantation forest during the wet and dry season

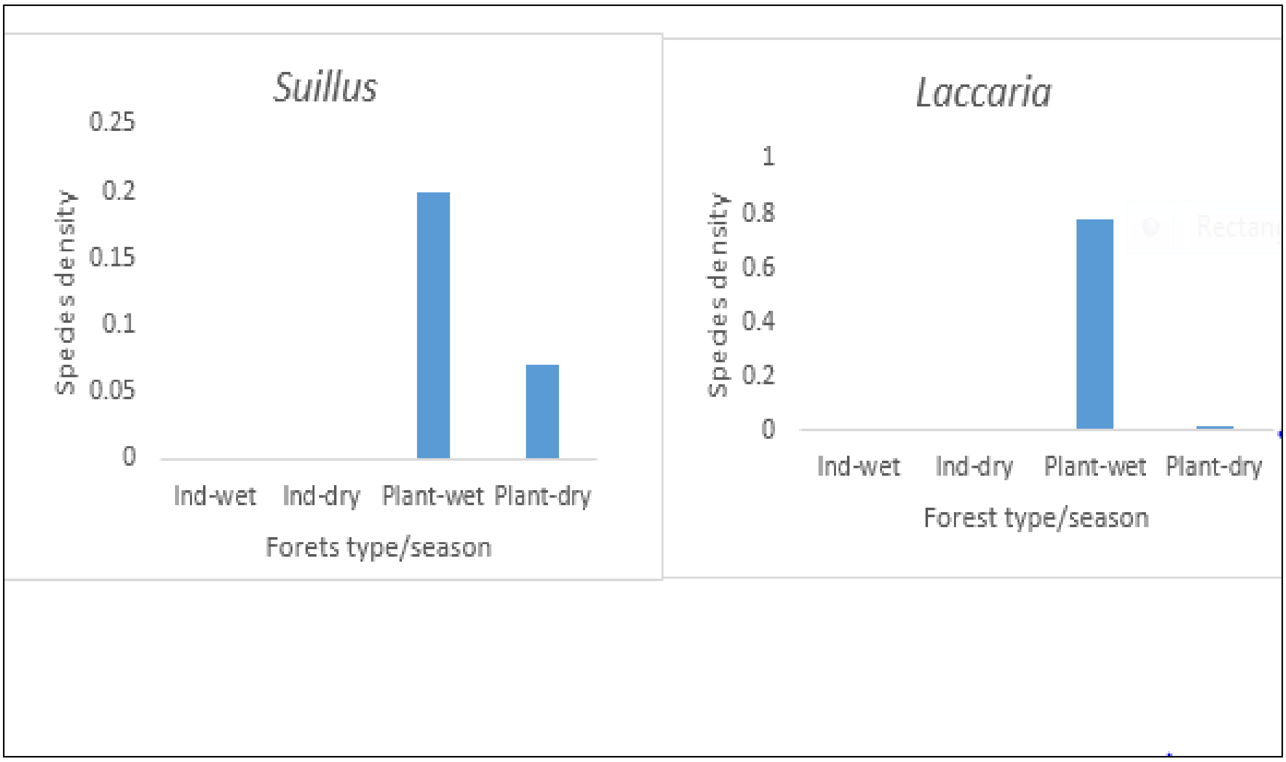

Fig. 8 – Ectomycorrhiza macrofungi occurring only in the plantation forest during the dry and wet season

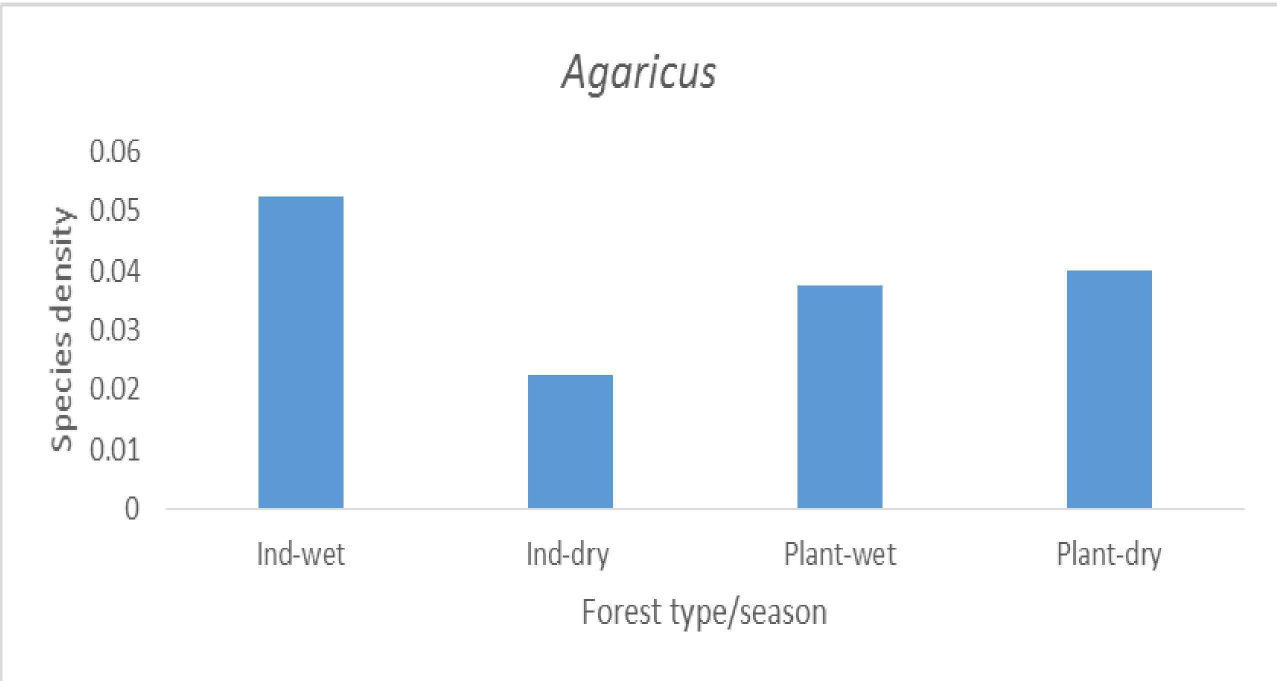

Fig. 9 – *Agaricus* distribution across the indigenous and plantation forest during the wet and the dry season

Effect of season and forest type on macrofungi diversity in Kereita forest

The macrofungi density and species richness were significantly affected by season, forest type and their interaction of the two ($p<0.05$), but season and forest type had no significant effect on the two species diversity indices -Shannon and Simpson diversity Index ($P>0.05$; Table 2). Macrofungi density and species richness were 2 times higher in indigenous forest compared to pine plantation (Table 3). The increase was more during the wet season in both indigenous and pine plantation compared to those encountered during dry season (Table 3). There was no significant difference in species diversity during the wet and dry season in both forest types (Table 3).

Table 3 – Effects of forest type and season on macrofungi diversity in Kereita forest

			Diversity indices and measures			
			Species richness (m)	Density (m^2.)	Shannon (H)	Simpson (I-D)
Interactions	**A x B**	Wet-Indigenous	10.13±1.41a	3.22±0.84a	0.84±0.14a	0.39±0.07a
		Dry-Indigenous	2.79±0.69b	0.19±0.09b	0.39±0.10a	0.211±0.06a
		Wet-pine	5.0±0.64a	0.15±0.05a	1.05±0.14a	0.53±0.07a
		Dry-Pine	2.0±0.26b	0.03±0.01a	0.51±0.11a	0.30±0.06a
	ANOVA	Forest type (A)	7.32(p<0.01)	54.46(p<0.01)	1.14(p=0.29)	2.25(p=0.1411)
		Season (B)	49.33(p<0.01)	50.89 (p<0.01)	13.03(p<0.01)	2.25(p=0.14)
		A x B	3.94(p<0.01)	36.14(p<0.01)	0.14(p<0.01)	0.31(p=0.58)

Key: Different letters within the same column show significant differences while same letters show no differences.

Discussion

The results from this study confirm diverse macrofungi assemblage in forested ecosystems in Kenya. Our study has revealed diverse macrofungi community comprising of 224 species distributed in 28 families. This is the first report showing a very diverse community of macrofungi in Kenyan forested ecosystems. Similar studies conducted in mountainous forested ecosystems reported 162 species (Kost 2002) while others in drier region like Maasai Mara and Coast region reported less than 50 species (Tibuhwa et al. 2011, Gateri et al. 2014). This difference could be attributed to the unique habitats within the Aberdare forest, which might favor the diversified groups of macrofungi in Kereita forest. Aberdare forest range is known to harbor a rich diversity of vegetation sustained by rich and red volcanic soils, which provides suitable conditions for the native forest (Muiruri 1974). Again, the main ecosystem within the Abedares is the rain forest characteristic of dense vegetation cover for a wide range of biodiversity (Maina et al. 2017). Only 24% of the macrofungi were identified to the species level. In this study, we used morphological methods mainly macro- and micro-morphological traits. Although these methods are used regularly, they are constrained by presence of numerous convergent morphologies that limit adequate discrimination in several genus (Martin et al. 2004, Tang et al. 2010). There is also possibility several fungi species from this forest are new to science and molecular approaches are being followed to confirm this.

Our species checklist matches earlier reports showing diverse macrofungi diversity in Kenyan mountainous indigenous forested ecosystems (Kost 2002). However, our study might have missed out several genera such as *Cerena*, *Cotylidia*, *Gryroon*, *Lopharia*, *Megasporospharia*, *Phaecogyroporus*, *Phaeogyroporus*, *Ripartitella*, *Schizopyrum* and *Scutellirinia* among the species documented by Kost (2002). Macrofungi species are known to have a short life and different species are known to appear in different times during the year (Tibuhwa et al. 2011). To have complete knowledge of macrofungi in a given habitat continuous observation and sampling for many years has been suggested (Osemwegie et al. 2010, Megersa et al. 2016). Since our results are based on study conducted only during the two seasons some of these species could have been missed during the sampling period. This is reported linear increase of species diversity with sampling effort especially in the indigenous forest indicating not all the species were sampled in the two forests during this study. This implies that more species can be recorded with additional sampling. Therefore, studies that are more detailed are necessary to reveal all macrofungi species.

Most of the macrofungi recorded in Kereita forest were saprophytic, mostly colonizing the litter-based, wood and soil organic substrates (Fig. 4). The high representation of saprophytic fungi in both forest types from the Agaricaceae family could be attributed to the fact that most of these species are capable of biodegrading many recalcitrant organic-based substrates present in indigenous forest (Lynch & Thorn 2006). In this study, the genus *Agaricus* was distributed across the two forest type probably due to its saprophytic nature linked to organic matter colonization that is available everywhere (Fig. 8). In addition, members of Agaricaceae are not known to associate with a given habitat, and are able to establish and thrive anywhere provided the conditions are suitable (Uzun 2010). They were found growing in soil organic matter (*Agaricus*), forest litters (*Cytolepiota*), animal dung (*Coprinus*) in grassland patches under pine plantation where grazing was noted. The species were largely found growing on wild animal dung, which is thought to contribute in enriching organic matter substrate suitable for macrofungi diversity in this region (Karun & Sridhar 2015). The high occurrence of Agaricaceae family could further be explained by the fact that the Agaricaceae members have thick spores that can remain viable in the environment for a very long period especially when the conditions are not favourable for their establishment (Priyamvada et al. 2017). Other predominant families in this study were Tricholomataceae and Mycenaceae mostly predominant during the wet season. The Mycenaceae family members are saprophytic species decomposing mainly litter based substrates. They are mainly favored by presence of dead twigs, leaf substrates while others occur on cowdung. The species were documented in both indigenous forests mainly in forest litter and in pine growing in cowdung. They are associated with small fruiting bodies that establishes at relatively shallow depth. This characteristic favours their appearance during the early rainy season and quick disappearance according to Enow et al. (2013). Tricholomataceae is a large and diverse family with most of the members being wood degraders. The high number of species belonging to the tricholomataceae in the indigenous forest during the wet season is linked to availability of diverse moist wood substrates. The wood-based substrates have been shown elsewhere to support high mushroom diversity (Osemwegie et al. 2010).

Ectomycorrhiza species only occured in the pine plantation and common genera known to associate with pine trees such as *Suillus*, *Chroogomphus*, *Laccaria*, and *Inocybe* were documented (Karim & Kasovi 2013). Other genera such as *Lactarius*, *Hebeloma* and *Rhizopogon* known to associate with pine trees were not documented (Kost 2002). Such variations are expected since pine trees are exotic to Kenya and only ectomycorrhiza species introduced during the afforestation program may exist (Kost 2002). Pine trees are among the major obligate hosts of ECM fungi, explaining high diversity of ECM in these forests. These species form symbiotic relationship with plant root where the plant provides fixed carbon to the fungus and in return, the fungus provides mineral nutrients, water and protection from pathogens to the plant (Tapwal et al. 2013). No ECM species were recorded in indigenous forests suggesting lack of mycorrhiza host species. Parasitic species belonging to the genus *Armillaria*, *Ganoderma* and *Phellinus* were recorded in the two land use types though they were few compared to other groups (Saprophytic and Ectomycorrhiza).The parasitic fungi in the forest ecosystem are a natural element if the pathogens are below a given population threshold. The fungus directly kills the trees opening the forest for the trees that demand light (Molina 1994). The dead wood is also a source of nutrients upon decomposition by other fungi. The parasitic fungi (*Ganoderma appalatum* and *Phellinus gilvus*) possess medicinal value, which can be sustainably obtained from the two forest types towards the growth of pharmaceutical industries (Tapwal et al. 2013).

Understanding how macrofungi populations and communities are affected by conversion of indigenous forest to other land uses is fundamental in estimating their diversity losses and in designing conservation measures. Our results show conversion of indigenous forest to plantation forest, alters macrofungi species composition and promotes development of a new community of macrofungi (Fig. 5). Indigenous forested ecosystems also harbored a wide range of macrofungi in terms of species density and richness compared to plantation forest (Claudia et al. 2015, Pushpa & Purushothama 2012). Saprophytic and parasitic species especially wood and litter decomposing species were more dominant in indigenous forest (*Armillaria*, *Pleurocybella*, *Cyathus* and *Galerina*, *Oudemansiella* and *Favolaschia*) while ectomycorrhiza species (*Suillus* and *Laccaria*) were found only in pine plantation (Figs 6–9). Our results are in line with several studies showing negative implication on the conversion of indigenous forest to single species tree plantation on macrofungi species composition (Paz et al. 2015). Other findings have also shown high species density and richness in the natural forest compared to planted plantation forest (Osemwegie et al. 2010, Claudia et al. 2015). Pristine indigenous forests are associated with favorable macro and microclimate (humid conditions, temperature), reduced anthropogenic interferences, litter fall dynamics, readily available degradable wood substrates, high plant diversity and composition (Pushpa & Purushothama 2012). Accumulation and availability of degradable substrates coupled by presence of diverse tree species favors high turnover of litter decomposing and wood rotting macrofungi (Sefidi & Etemad 2015, Yamatisha et al. 2015). Litter decomposers are specialists in degrading the recalcitrant organic compounds in the litter materials to unleash nutrients and carbon to the soil (Wal et al. 2013), while wood-degrading fungi decomposes wood type substrate to provide microhabitats important for soil dwelling fungi and other organisms (Rajala et al. 2015).

About 70% of macrofungi species found in indigenous forest were not encountered in pine plantation. This suggests loss of macrofungi species that were previously associated with indigenous forest when the forest was converted to single species plantation forest. Conversion of indigenous forest to plantation forest causes drastic disturbance of natural ecosystem that destroys richer plant communities responsible for generating diversified microclimates and supporting different types of substrates such as diversified fine litter and dead wood in various sizes and stages of decomposition (Moore et al. 2004, Waldrop et al. 2006). Such changes alter the original environment creating drastic changes to degradable substrate from older and more diverse plant community in indigenous forest to woody and litter substrate dominated by a singletree species (Heilmann-Clausen & Christensen 2003, 2004, Norden et al. 2004, Packham et al. 2002). Single species plantation forests have low plant diversity and high human disturbance linked to sivicultural practice such as thining and pruning of the trees (Baral et al. 2015). Silvicultural practices are known to reduce the canopy cover to some extent causing the forest to be more open. As a result, high humidity and increased temperatures are experienced thus affecting the macrofungi fruitbody formation (Baral et al. 2015). The studied pine plantation forests was a single tree species forest making it less favorable habitats for diverse range of macrofungi species due to low woody and litter substrates, forest composition changes due to succession and disturbance which ultimately affects macrofungi growth and development (Karim & Kasovi 2013). In this study, pine plantation had very low woody and litter substrates. It was also highly grazed explaining the low species richness and density. Also only, few species in the genera *Oudemansiella, Favolaschia, Campanella* and *Ripartitella* have the ability to utilise the wood substrates of pine plantation contributing significant difference in species composition between the two land use types. This recommends need for detailed study of macrofungi fungi species before any changes of land uses are introduced and detailed conservation measures to affected species. This will ensure sustainable conservation of these species for future research, restoration programs and their use in food and pharmaceutical industries. Kasel et al. (2008), Claudia et al. (2015) confirms that change in land use results to shift in species composition of macrofungi whereby plantation and indigenous forest support distinct groups.

Seasonality was a major factor explaining changes in macrofungi species community. Macrofungi species were more during wet season compared to the dry season in both forest types. Dominant species during wet season were fleshy macrofungi while non-fleshy fungi (polypore) were present in both seasons. This phenomenon could be well explained by adequate moisture levels in substrate and atmosphere alongside favorable temperature during the wet season (Priyamvada et al. 2017). Climate is a critical factor in the fruiting, productivity and distribution of all fungi (Boddy et al. 2014). Certain agaric species are also known to be associated with closed canopies of forests whereby fruiting may be sporadic and limited to the wet season (Karim & Kasovi 2013). The high number of soil inhabiting fungi during the wet season is also linked to substantial amounts of decaying woody fragments, which eventually turns to soil organic matter, and hence supports a wide range of soil resident fungi (Rajala et al. 2015). The dry season is not favorable for the development of fleshy fruit bodies and instead both annual and perennial polypores are prevalent during this time (Enow et al. 2013, Yamatisha et al. 2015). Woody perennial polypore are able to survive both in the dry and moisture-rich periods due to their hard external upper fruiting body, deeply rooted vegetative mycelium into tree trunk and presence of long and narrow hymenial tubes that help the fungus remains in a relatively saturated state even in dry environmental conditions. They also have thick and pigmented spores that are not affected by harsh conditions and are able to survive for a very long time in the environment (Priyamvada et al. 2017). Therefore, polypores are considered to experience minimal effect to seasonality or annual variation. The present study coincides with the findings of Karim & Kasovi (2013) who studied the macrofungi of deciduous forest in Iran and explained that seasonality is critical in distribution of macrofungi. *Armillaria*, *Pleurocybella*, *Cyathus* and *Galerina* were common species with high density during the wet season in the indigenous forest. The prevalence of polypores in the indigenous and plantation forest during the dry and wet season is mainly because both annual and perennial polypores are hardy wood decomposers. They are considered to experience minimal effect in regard to seasonality or annual variation (Priyamvada et al. 2017).

The diversity indices did not reveal significant difference between the different land uses, but plantation forest seemed to have higher diversity. In this regard, plantation forest might equally support diverse community of macrofungi as the indigenous forest, but species composition might differ among forests (Tapwal et al. 2013). Preference of macrofungi towards particular habitats may be driven mostly by ecological role of the species, as evidenced by the presence of ectomycorrhizal species in the forests (Pradhan et al. 2013). The ectomycorrhizal species in the plantation were introduced during the afforestation when the exotic trees could not establish without the symbiotic macrofungi. Only a few saprophytic species survived and it was due to their ability to utilize new sources of wood (Kost 2002). This implies that conversion from indigenous forest to exotic plantation forest alters macrofungi species diversity and promotes a new community of macrofungi species (Claudia et al. 2015).

Conclusion

Indigenous and plantation land use types are a haven of diverse and distinct macrofungi communities. Change in land use results in changes of macrofungi composition and losses of indigenous species not compatible with introduced environment and tree species. Indigenous forest supports a rich macrofungi community compared to plantation forest. Seasonality is a key factor in the fruitification and distribution of macrofungi and the diversity of fleshy fungi dominates during the wet season. The study forms a baseline on the diversity of macrofungi for further assessment of forested ecosystems.

Acknowledgement

The authors thankfully recognize the immeasurable support of Kijabe Environment Volunteers KENVO staff (specifically Steven Kamau) for technical support during the field work, Kenya Forest Service (KFS) for granting us permission to conduct the study within the forested ecosystems, National Museums of Kenya for providing the working space and Tropical Biology Association (TBA) for funding this work.

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